Distribution and length-weight relationships of Tunas and Tuna-like Fishes around Ceylon

By

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INTRODUCTION

TUNAS and tuna-like fishes have contributed considerably towards the increase in fish production from Ceylon's coastal waters, during the last five years and in this blood fish group lies a potential resource for a further increase in production. Consequently considerable attention is being paid to the study of these species. Length frequency sampling of these species are being carried out and quite often it becomes necessary to convert catch in terms of weight to catch in terms of number, when estimating apparent abundance of the stock. The length-weight relationship in addition to its usefulness in converting length frequency data to weight frequency data for such purpose, is of general value to biologists and even to fishermen. The six species studied are yellowfin tuna (*Thunnus alacares* (Bonneterre)), skipjack tuna (*Katsuwonus pelamis* (Linnaeus) Mackerel tuna (*Euthynnus affinis* (Cantor)), frigate mackerel (narrow corseleted *Auxis thazard* (Lacepede) and broad corseleted *A. rochie* (*Risso*)) and bonito (*Sarda orientalis* (T & S.)).

SOURCE OF DATA

Length frequency sampling has been stratified according to fishing area, fishing season, fishing gear and the craft used. The sea around Ceylon has been arbitrarily divided into seven areas and the positions of the boundaries between areas have been fixed after giving consideration to the latitudinal and longitudinal lines crossing the island (Fig. 1a). Sampling was conducted at thirty-seven fish landing centres around the island, between 1964 and 1966. Adequate sampling from all areas was not achieved due to the reluctance on the part of the illiterate fishermen and middlemen to permit such sampling, especially weight measurements of fish. Though the central fish market in Colombo receives fish from all these areas, unbiased sampling could not be made because fish are sorted according to size, value, time of landing the catches and the demand for any particular variety in Colombo. Further, stratification by gear and craft is not possible. The samples for this study were examined when the fishes were brought ashore and before cleaning or icing. Measurement of the fork length (cm), from tip of the snout to the cartilaginous median part of the caudal fin, was made with the wooden calliper constructed for the purpose. Weight measurements were taken with a spring balance marked to read in pounds and ounces. The weight measurements were always converted to ounces as most of the samples were small and even in the case of the yellowfin the average size caught was around 50 cm.

STATISTICAL METHODS

Calculation of the relationship was based on the usual formula $W = aL^b$ or $\log_{10} W = \mathrm{Log}_{10}\, a + b\, \mathrm{Log}_{10} L$ (L is the length, W is the weight, b is the regression co-efficient and a the intercept on Y axis). The length-weight measurements were converted into common logarithm and the linear regressions for each species in each area were calculated applying the principle of least squares. A common regression equation for each species was calculated by pooling the data from all the areas.

Heterogeneity of the regression coefficients of each species from the different areas was tested by the analysis of covariance (Goulden, 1952). This test was not carried out in the cases of bonito and the A. rochei, as the sample sizes from the respective areas were extremely small.

Fiducial limits for the common regression coefficients were calculated for 5% level ($b + t^{0.05}$ sb is the standard error of the regression coefficient and $t_{0.05}$ obtained from table for 't' at $p = 0.05$ and degree of freedom n-2).

DISTRIBUTION OF EFFORT AND SPECIES

Biology and densities of distribution of blood fish around Ceylon, were briefly discussed earlier (Sivasubramaniam, 1965). The distribution of effort concentrated on blood fish, proportions of the various species caught by each type of gear are illustrated in figure 1a. Fishing villages are very closely distributed along the entire coastline except in the southeast corner. Fishing is limited to a distance of 25 miles (Average 15) from the beach and each trip seldom exceeds 24 hours. In the area marked NW and SE there is hardly any attempt to concentrate on blood fish fishery and the catches are sporadic. Generally the catches are made from mixed schools of blood fish and the number of species in the school will depend quite often on the size range, the number of species declining with increasing size range. However, during the peak fishing seasons one species will be dominant and during such a period the schools are concentrated in one area. This trend and the observation that the peak fishing seasons of the adjacent areas always do not appear in any sequence has made it necessary to consider whether the blood fish exploited from all these areas originate from a common stock.

REGRESSION ANALYSIS

Yellowfin tuna:—Regression coefficient for the four areas are given in table 1 and the regression lines are shown in figure 1. Each line also indicates the size range of the sampling from the respective area. Very significant heterogeneity of the regression coefficients was observed ($F = 6$, d.f. 3,84 significant at $p = 0.01$) as shown in the same table. The size range for area 'E' was so small that a positive value of 'a' appeared. The common regression calculated may be represented by the equation

$$Y = 9.114 \times 10^{-4} X^{2.8097} \text{ or } \operatorname{Log} Y = 2.8992 \operatorname{Log} X - 3.0403$$

and graphically as in figures 2 and 3.

Skipjack tuna:—Table 2 gives the linear regressions for the four areas compared. The size ranges as evident from figure 4 indicates a very small range for area 'W'. The regression coefficients were found to be significantly heterogeneous (Table 2). The regression values for the area 'E' was observed to be very significantly different from those of the other areas and it may be noted that much of the samples from this area were spent females. The common regression equation obtained is

$$Y = 9.441 \times 10^{-4} X^{2.8977} \text{ or } \operatorname{Log} Y = 2.8977 \log X - 3.0250.$$

These are illustrated in figures 5 and 6.

Mackerel tuna:—Table 3 and figure 7 give the regression coefficients and the regression lines respectively, for the four areas. An extremely high value of 'F' was obtained in the test for heterogeneity. The samples from one area included juveniles which occur frequently in the commercial catches of that area. It was also found that the value of 'F' may be made smaller but not below a significant level, if the samples from area 'E' are eliminated from the test. The common regression equation obtained is

$$Y = 4.838 \times 10^{-4} X^{3.0249} \text{ or } \operatorname{Log} Y = 3.0249 \operatorname{Log} X - 3.3154.$$

(Figures 8 and 9 and 9 give the regression lines.

Frigate mackerel (narrow corseleted form):—This is the more common variety of frigate mackerel in Ceylon waters. Regression coefficients and the corresponding regression lines are shown in table 4 and figure 10, respectively. A very significant level of heterogeneity was found. The common regression equation obtained (figures 11 & 12) is given as

$$Y = 1.780 \times 10^{-4} X^{3.3338} \text{ or } \operatorname{Log} Y = 3.3338 \operatorname{Log} X - 3.7497.$$

Frigate mackerel (Broad corseleted form):—Appearance of this species in the coastal waters is highly seasonal and the abundance relatively less compared to that of the narrow corseleted form. However when this species appears, usually in the areas ' SW ' and ' E ', it is almost always in extremely large shoals or aggregates. The size range entering the fishery (Beach seine and troll) is very narrow. Because of the limitations of availability and the small size range entering the fishery, a comparative study has not been possible up to now. The length-weight relationship for this species is calculated as

$$Y = 2.598 \times 10^{-6} X^{4.6315} \text{ or Log } Y = 4.6315 \text{ Log } X\text{-}5.5854.$$

This is represented graphically in figure 13.

Bonito:—This species is not caught in noticeable quantity to be of any commercial significance in Ceylon, at present. It has been observed in catches from all areas except ' SE ' and ' E '. The smaller sizes are seen in the catches from northern areas (NW, NE and W) whereas those from ' S ' and ' SW ' have generally been relatively larger in size. The relationship between length and weight is shown in figure 14 and is represented by the equation

$$Y = 5.375 \times 10^{-4} X^{2.9582} \text{ or Log } Y = 2.9582 \text{ Log } X—3.2697.$$

DISCUSSION

It is quite evident that anomalies have been caused by the differences in sample size and size range, from the four areas. When size ranges for four areas are distinctly different from one another as in the case of yellowfin tuna (Fig. 1) or when the size range covers the juveniles and adults in one area, adults or spent females in others, significant level of heterogeneity should perhaps be expected. Further, absence of sampling during the same seasons and similar gear, from all these areas introduces considerable bias. Existing condition of the fishery is such that it would not be correct to assume homogeneity of regression coefficients of all the sampling as well as that for between seasons, within an area. It is also observed that in almost all these cases the regressions for area ' E ' deviated from those of the other areas.

Considering these factors and also the fact that these regressions are for the main purpose of inter-converting length and weight frequency groupings, the common reqression equations will suffice unless the morphometric and chromatographic comparisons of these species from the east coast (bordering the Bay of Bengal) and the west and south-west coasts (bordering the Arabian sea) which is being made, proves anything to the contrary.

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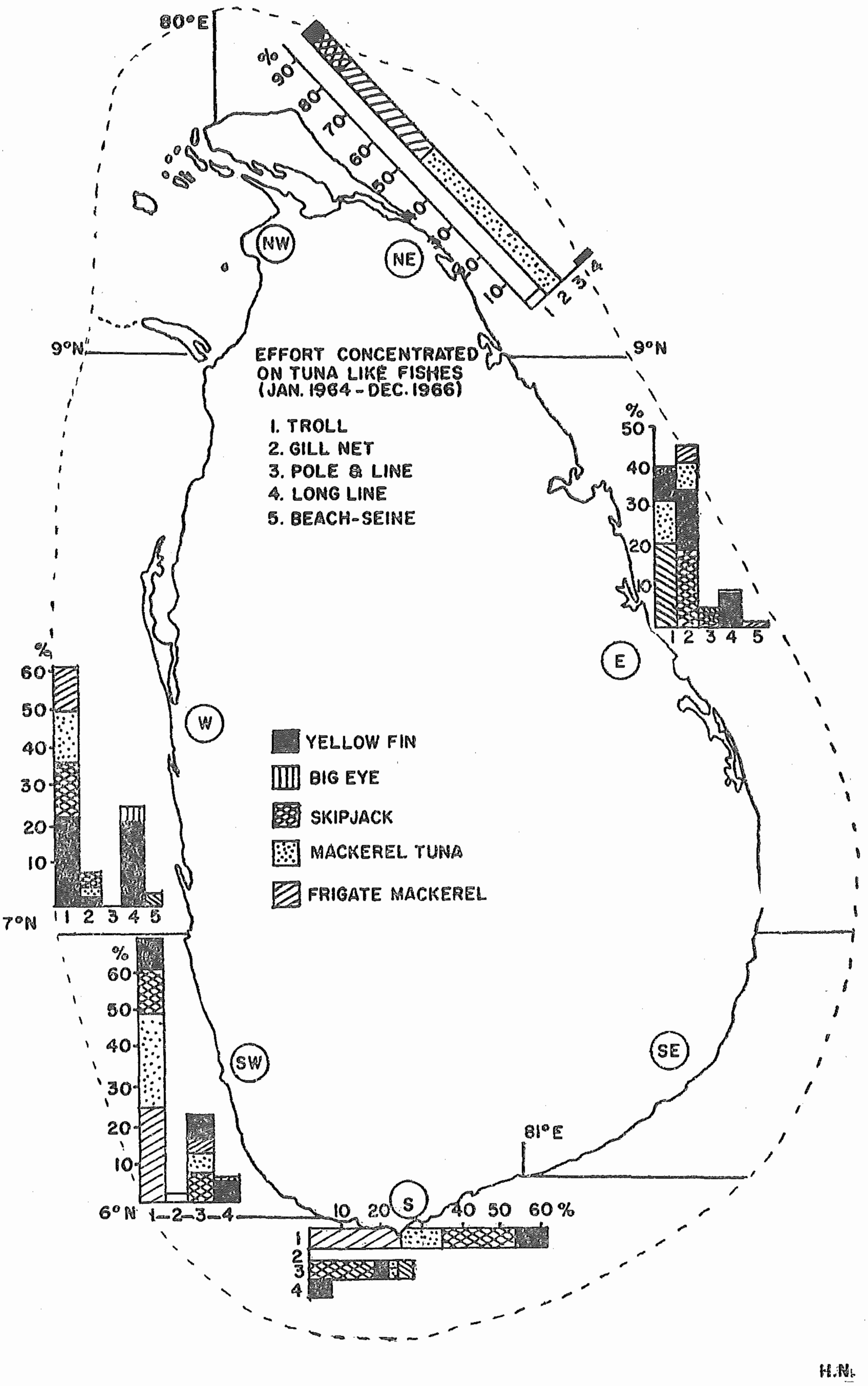

Fig. 1a. Distribution of effort on blood fish species around Ceylon.

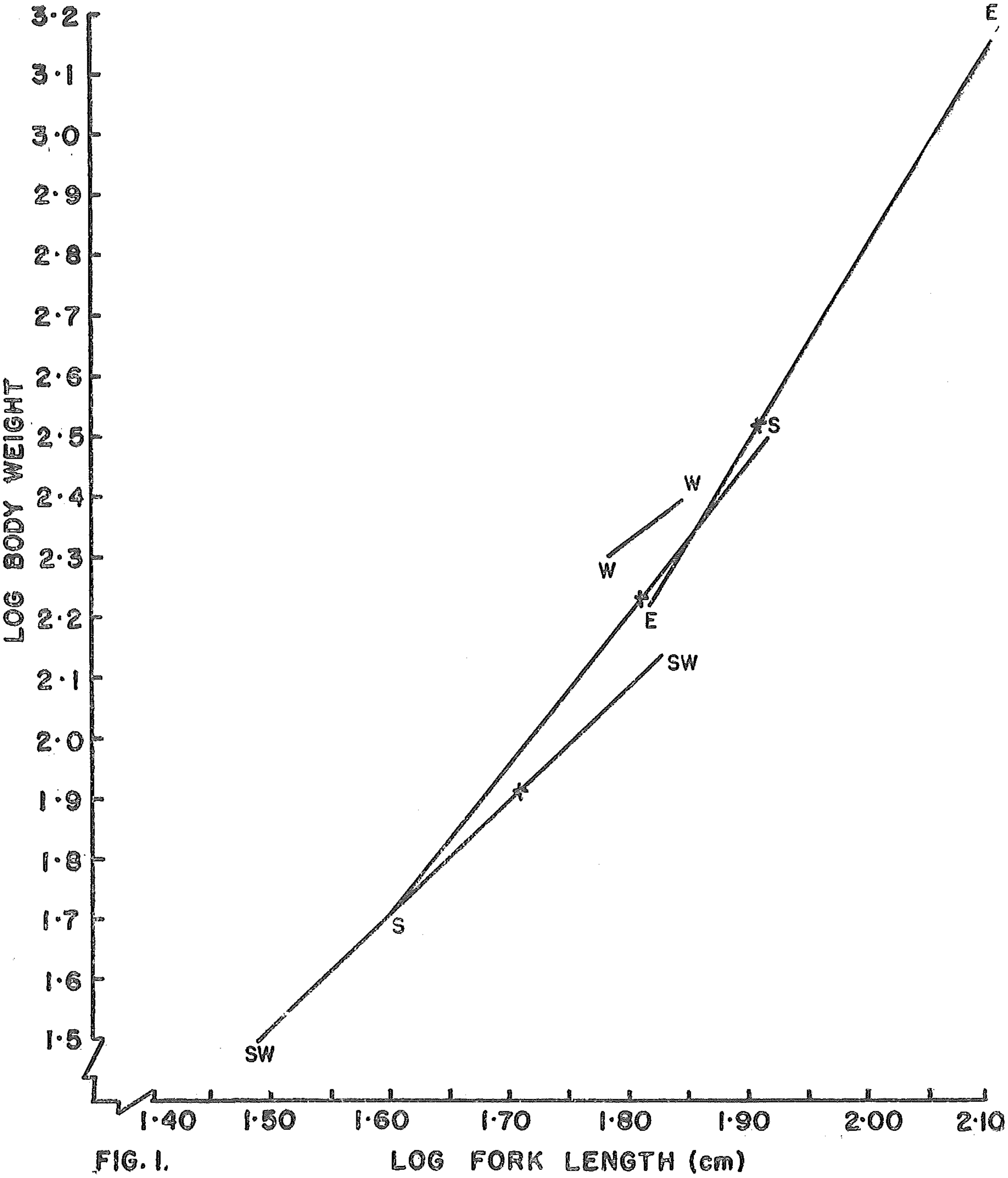

Fig. 1. Length-weight regression lines for yellowfin tuna, by area.

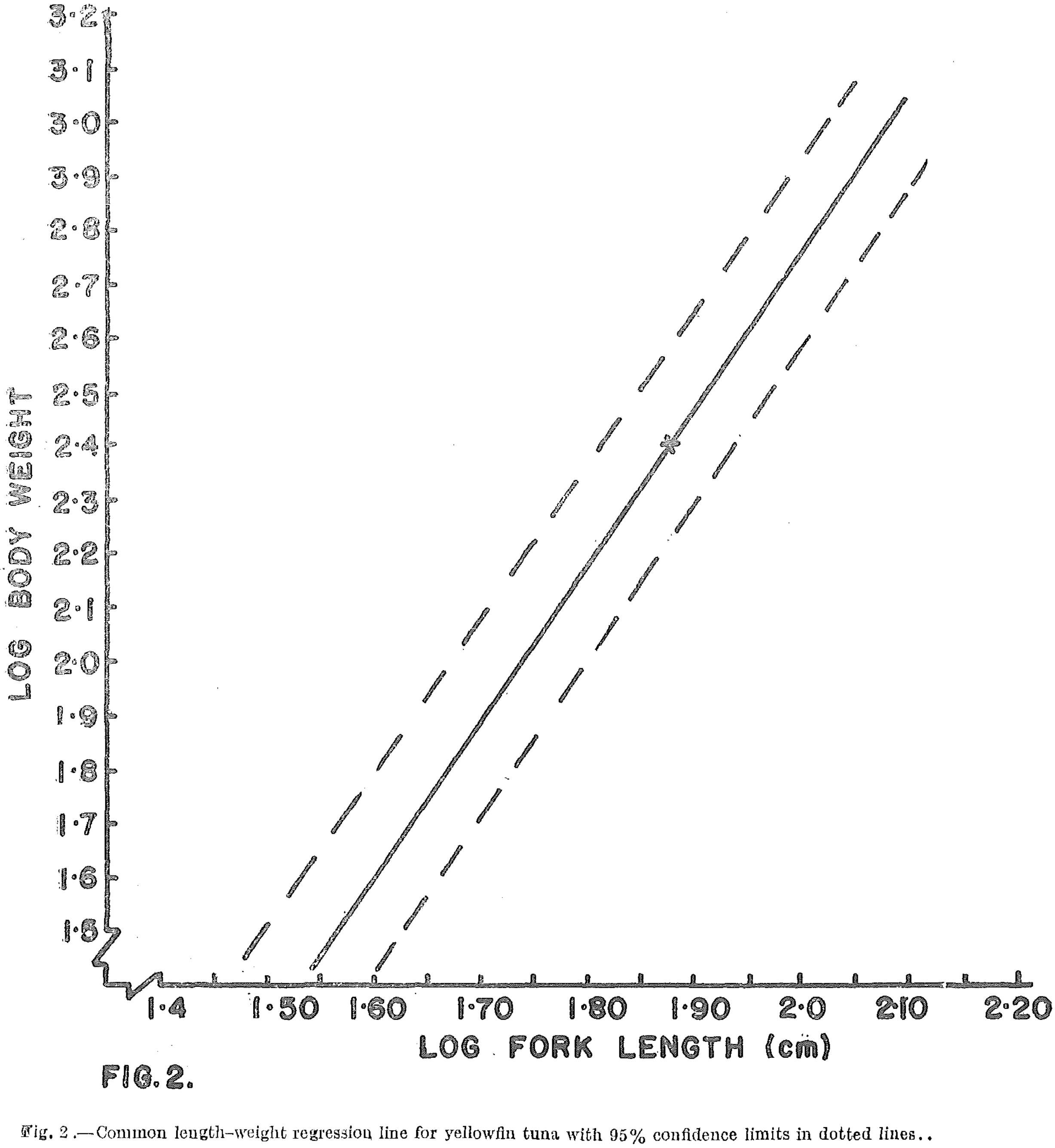

FIG. 2.

Fig. 2.—Common length-weight regression line for yellowfin tuna with 95% confidence limits in dotted lines..

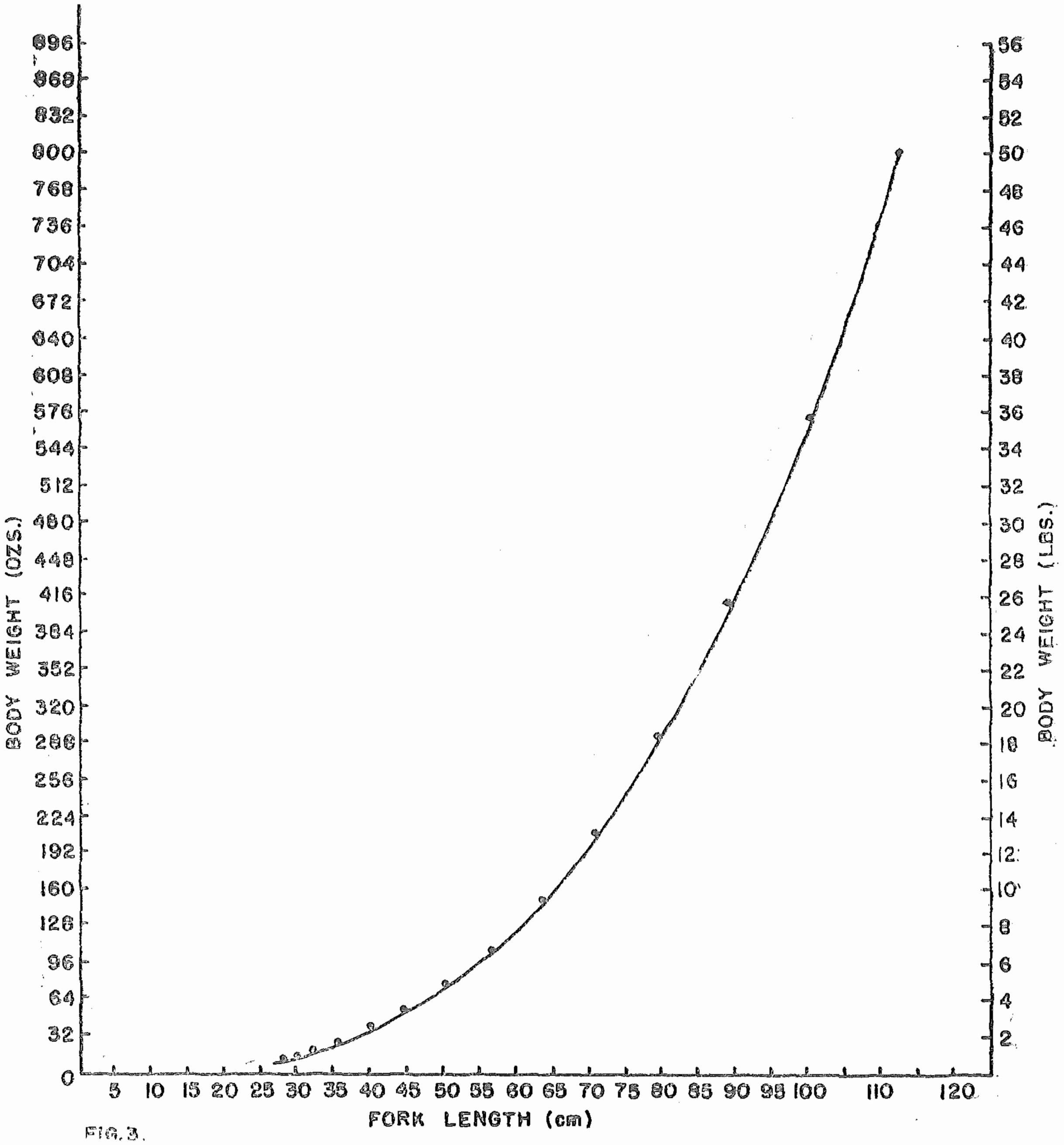

FIG. 3.

Fig 3. Length - weight relationship for yellowfin tuna.

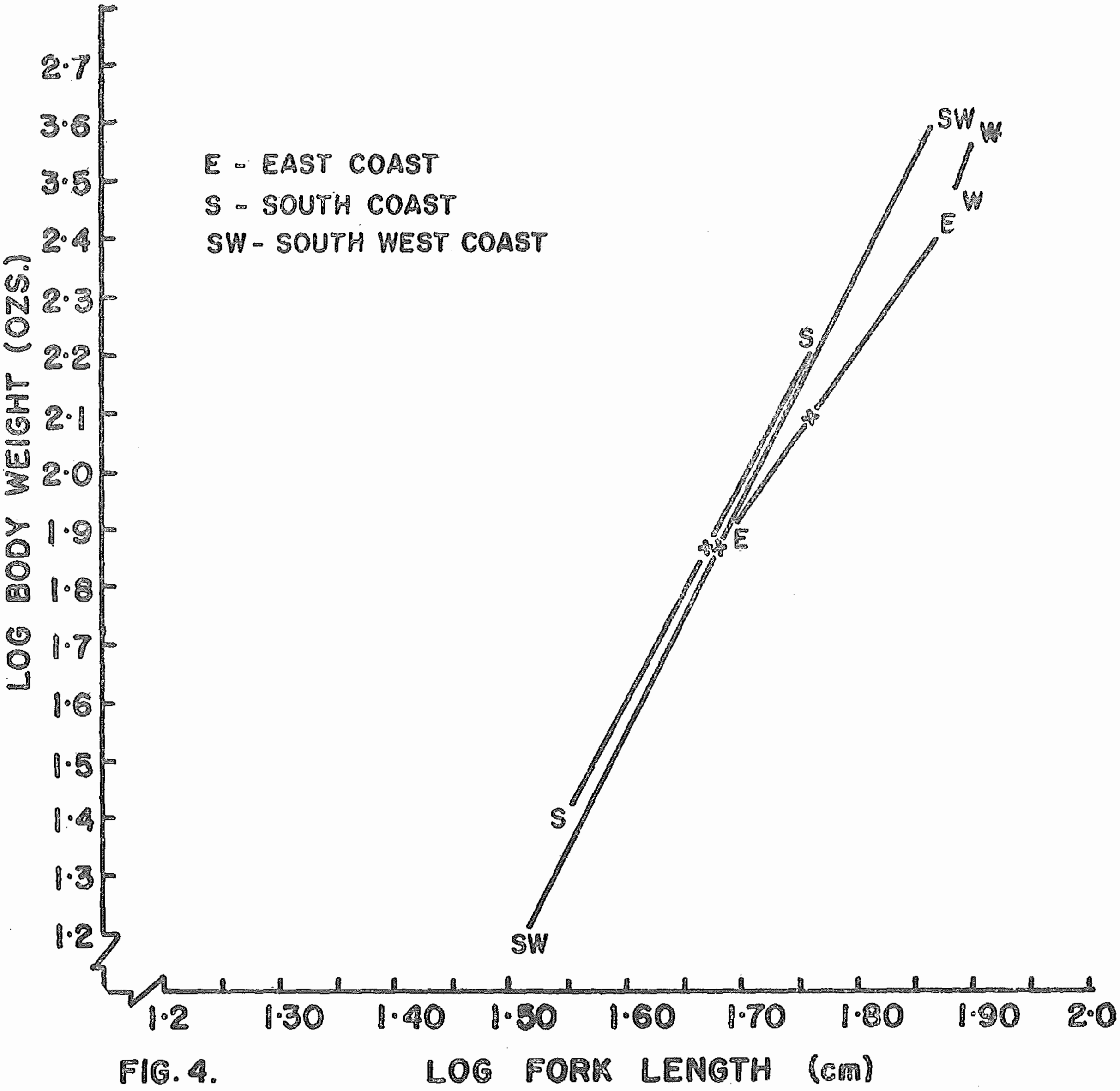

Fig. 4.—Length-weight regression lines by area, for skipjack tuna.

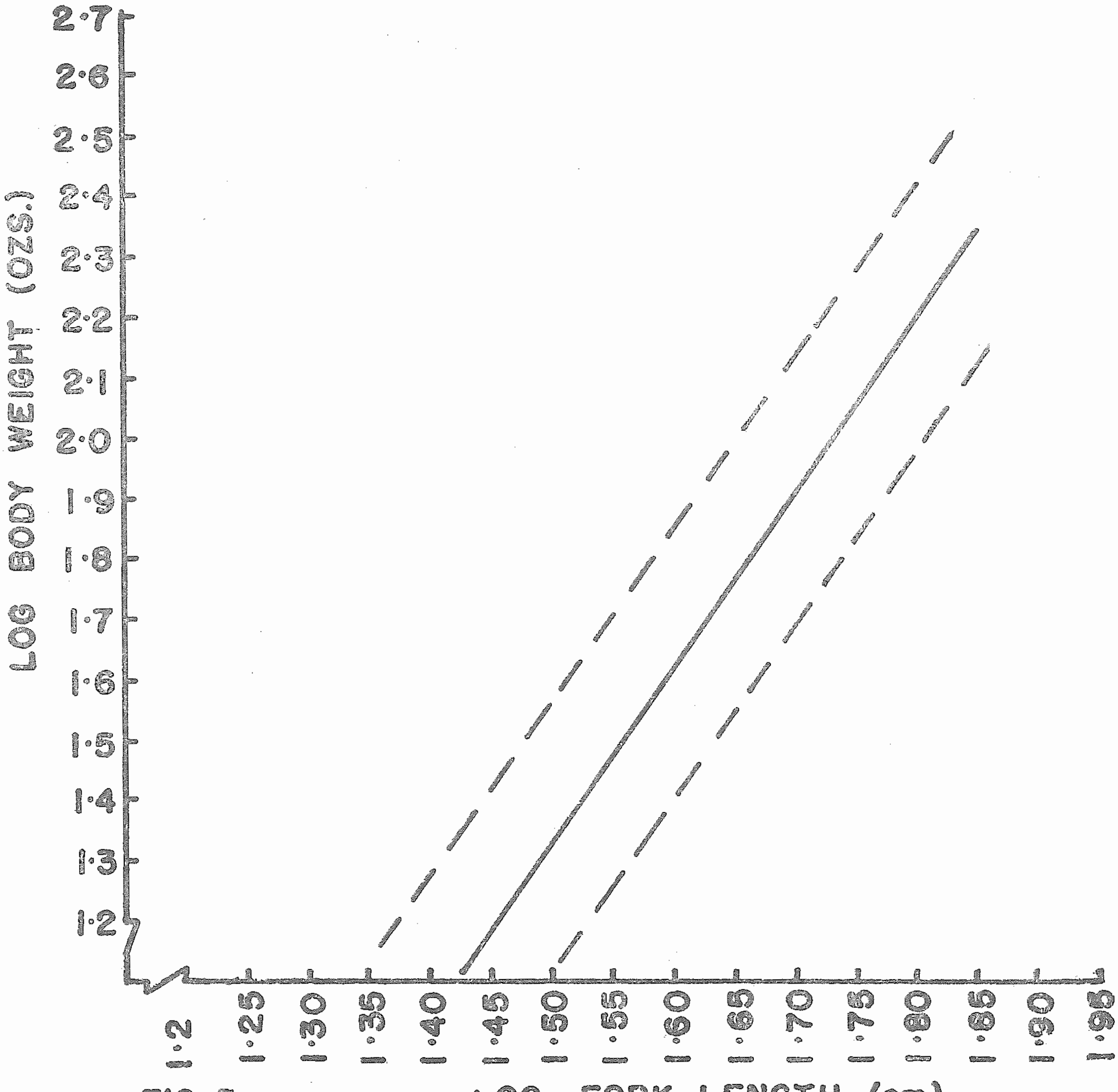

FIG. 5.

Fig. 5.—Common regression line for skipjack with 95% confidence limits in dotted lines.

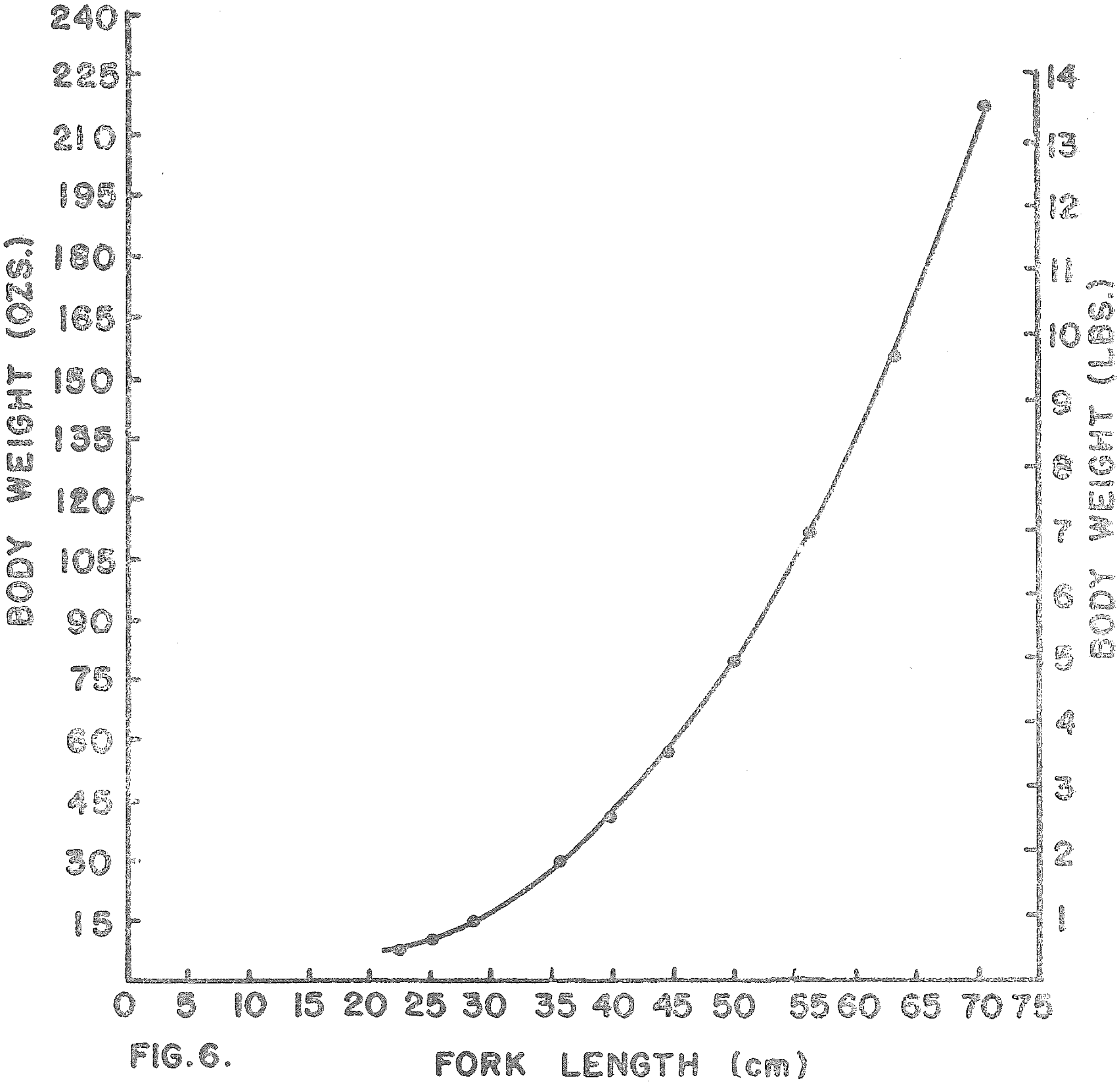

Fig. 6.—Length-weight relationship for skipjack tuna.

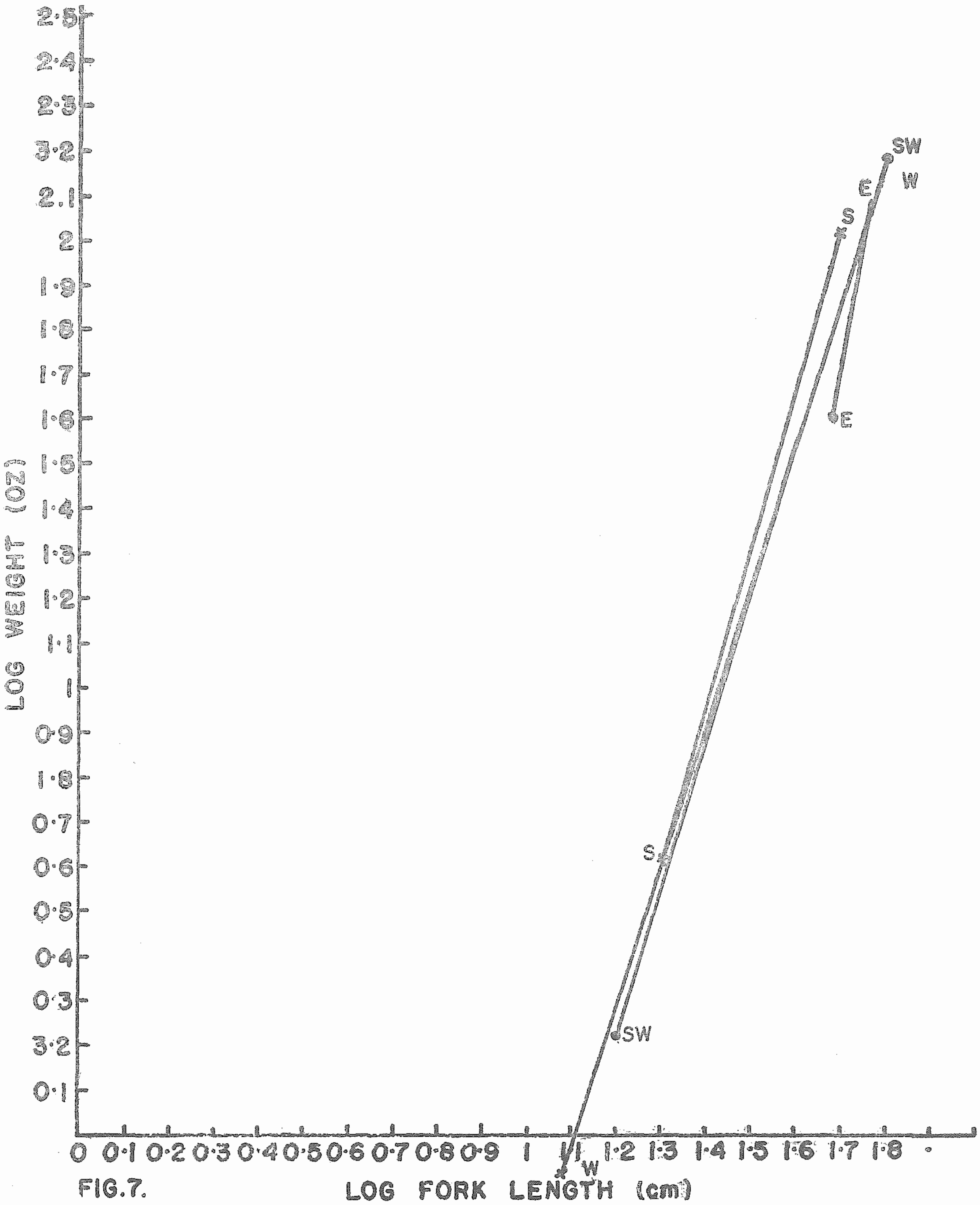

FIG.7.

Fig. 7.—Length-weight regression lines by area, for Mackerel tuna.

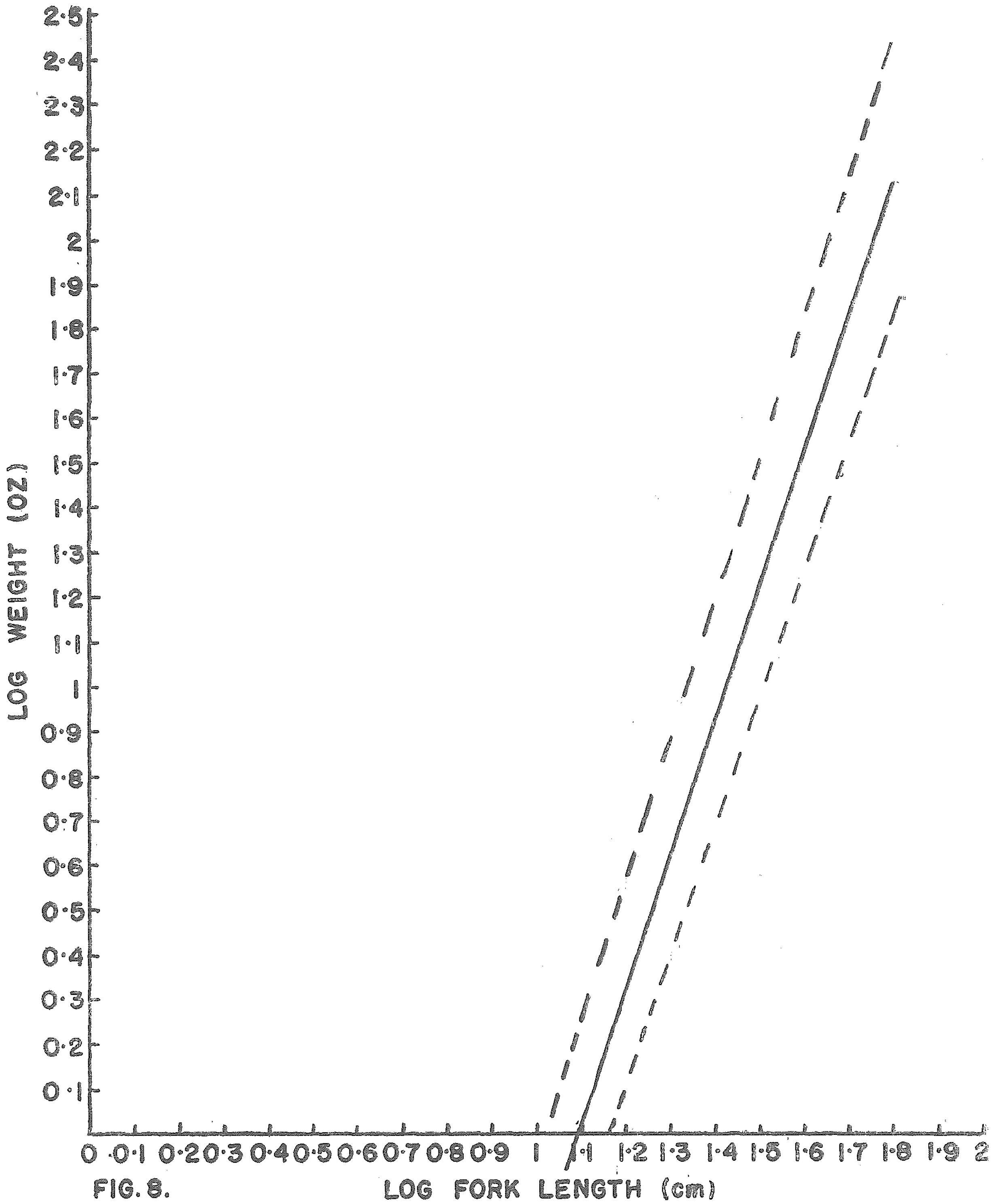

Fig. 8.—Common regression line for mackerel tuna with 95% confidence limits in dotted lines.

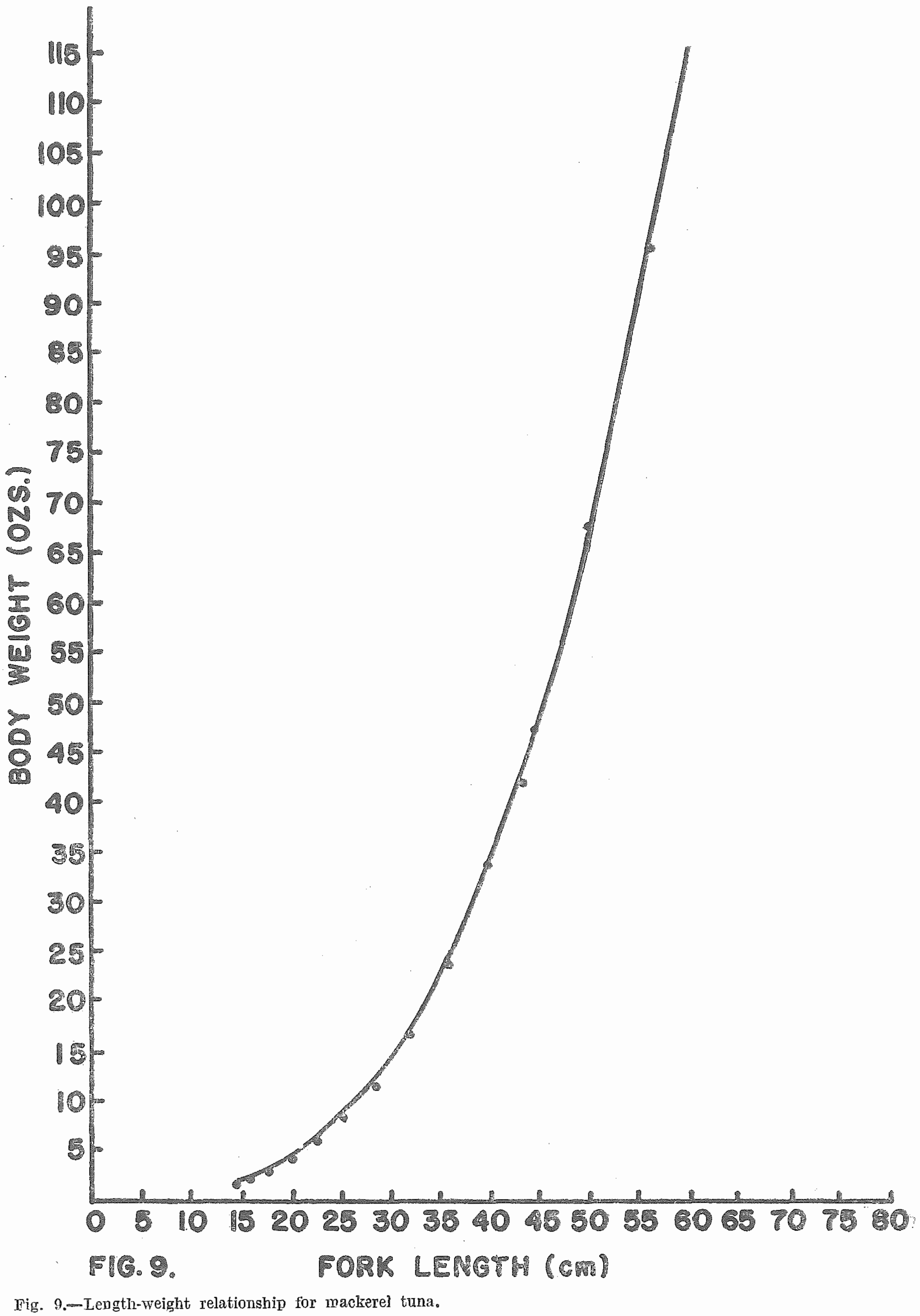

Fig. 9.—Length-weight relationship for mackerel tuna.

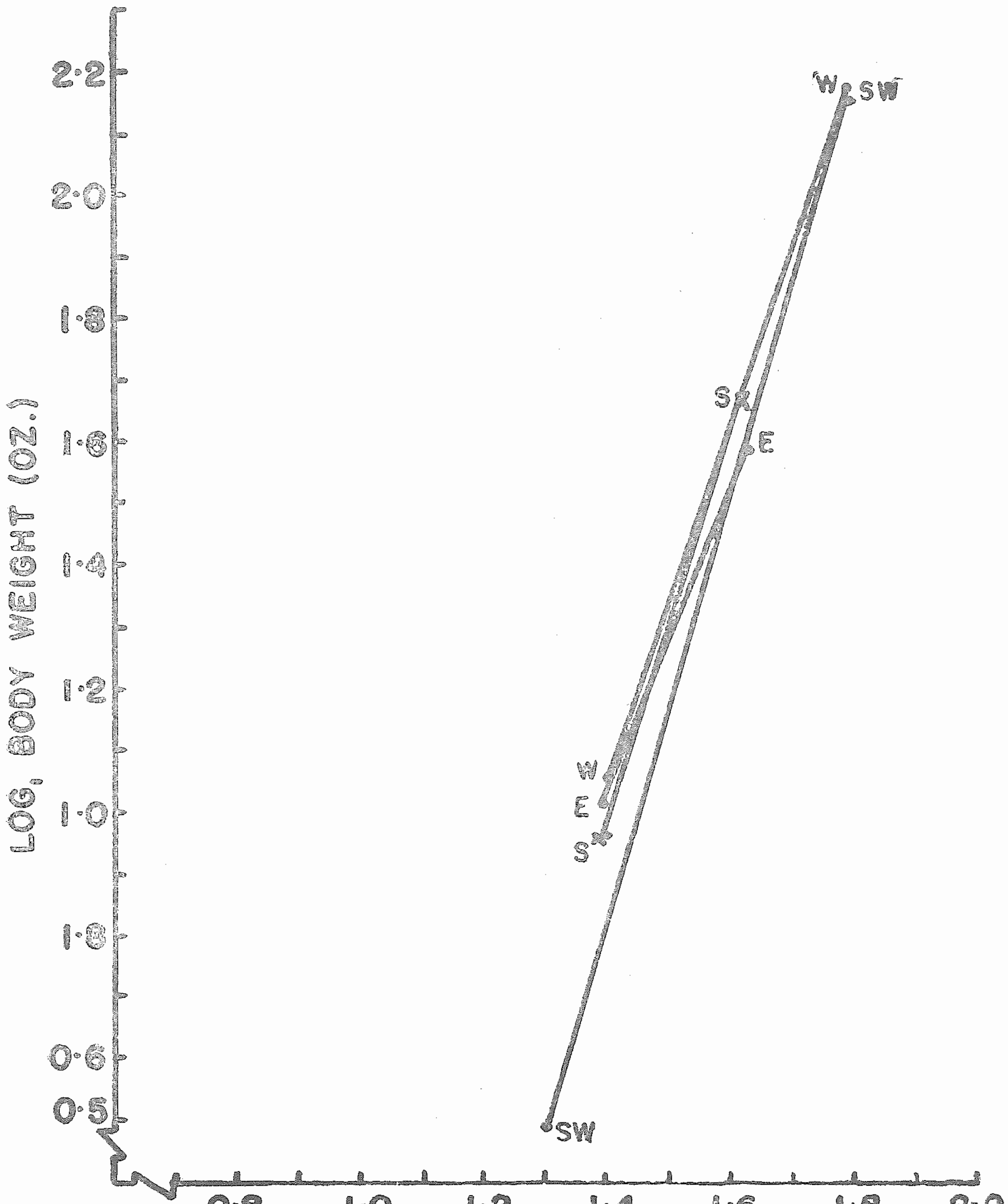

FIG.10. LOG FORK LENGTH (cm)

Fig, 10.—Length–weight regressian lines by area for frigate mackerel (A. thazard).

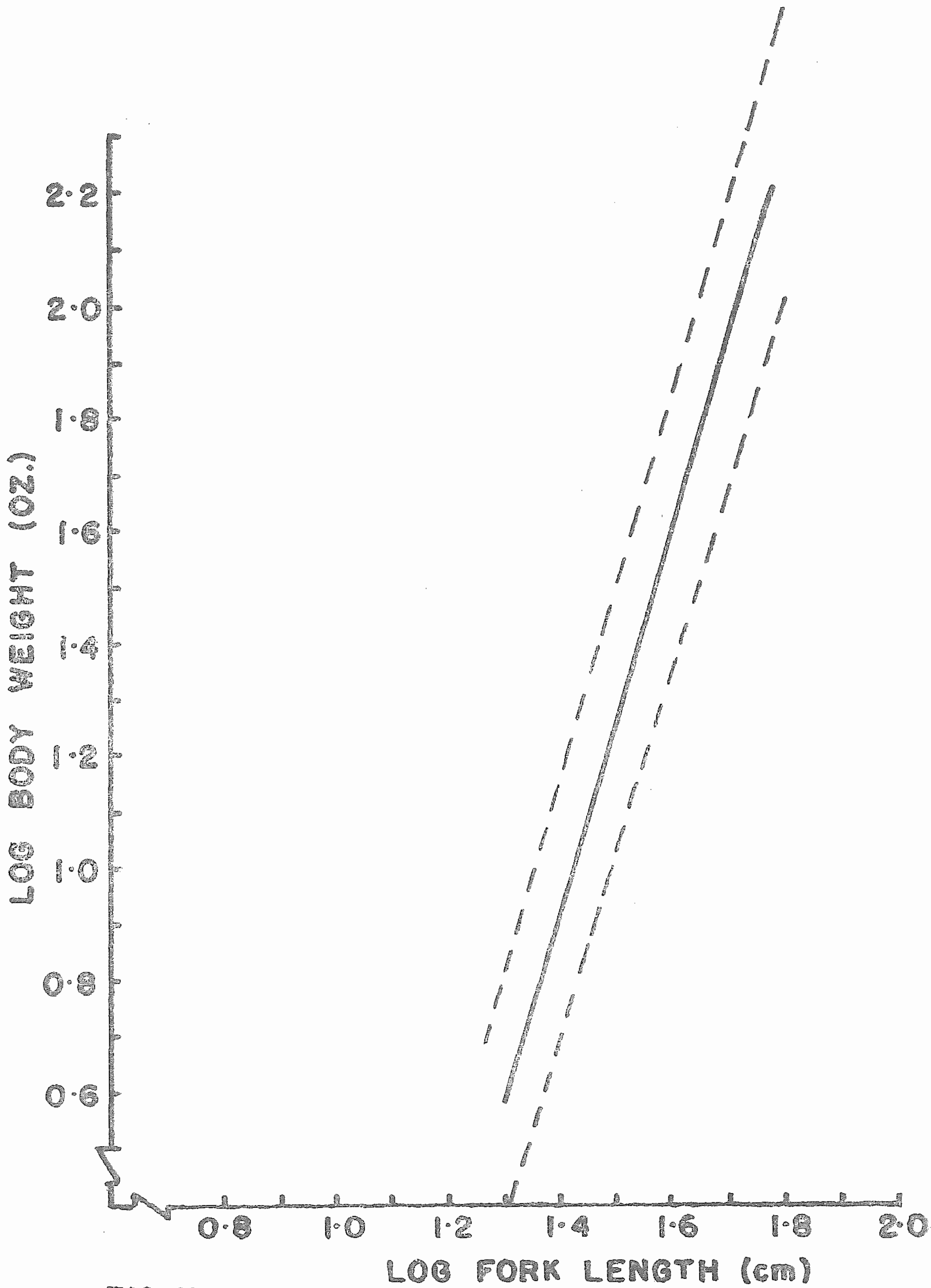

FIG. 11.

Fig. 11.—Common regression line for A. thazard with 95% confidence limits in dotted lines.

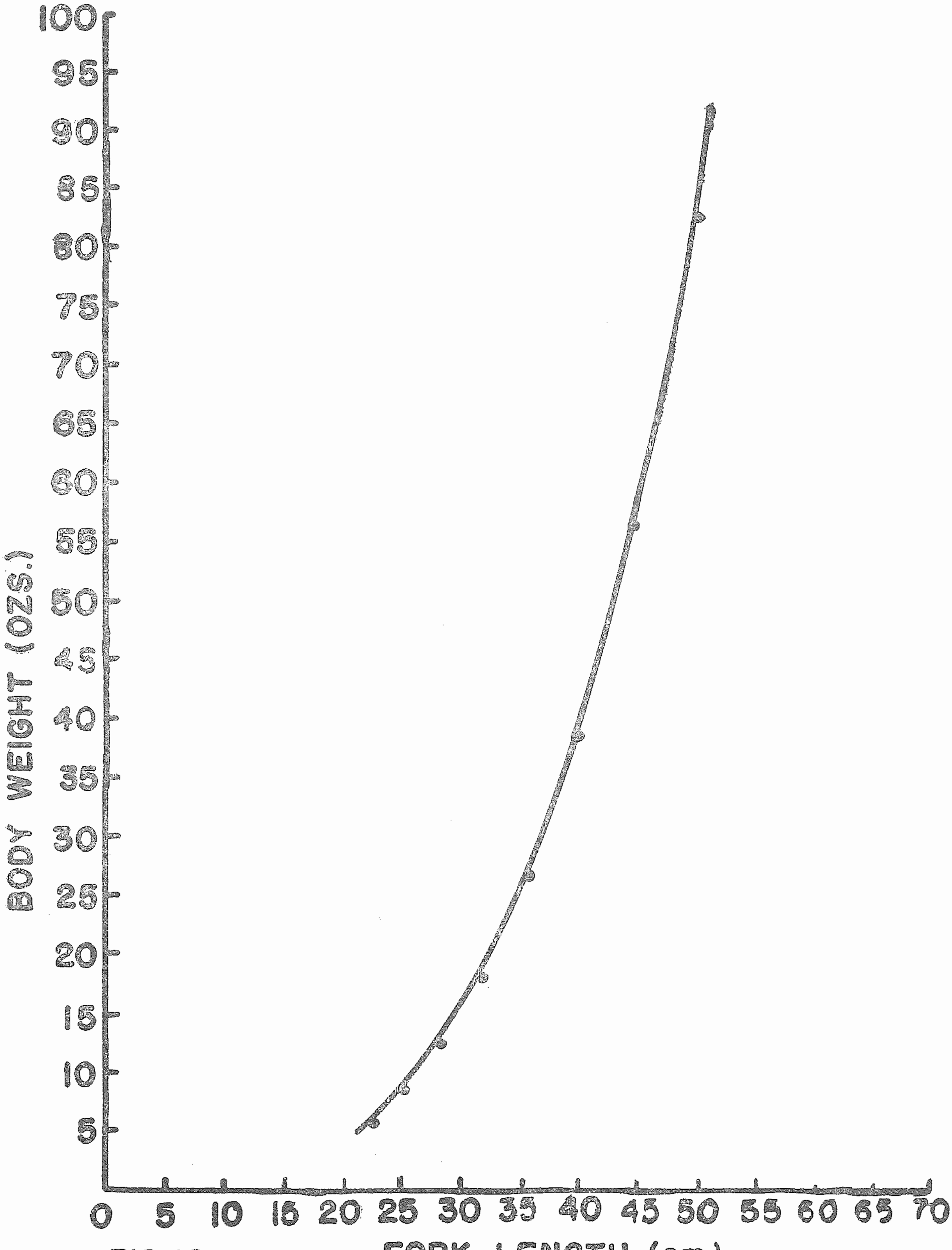

Fig 12.—Length and weight relationship for A. thazard.

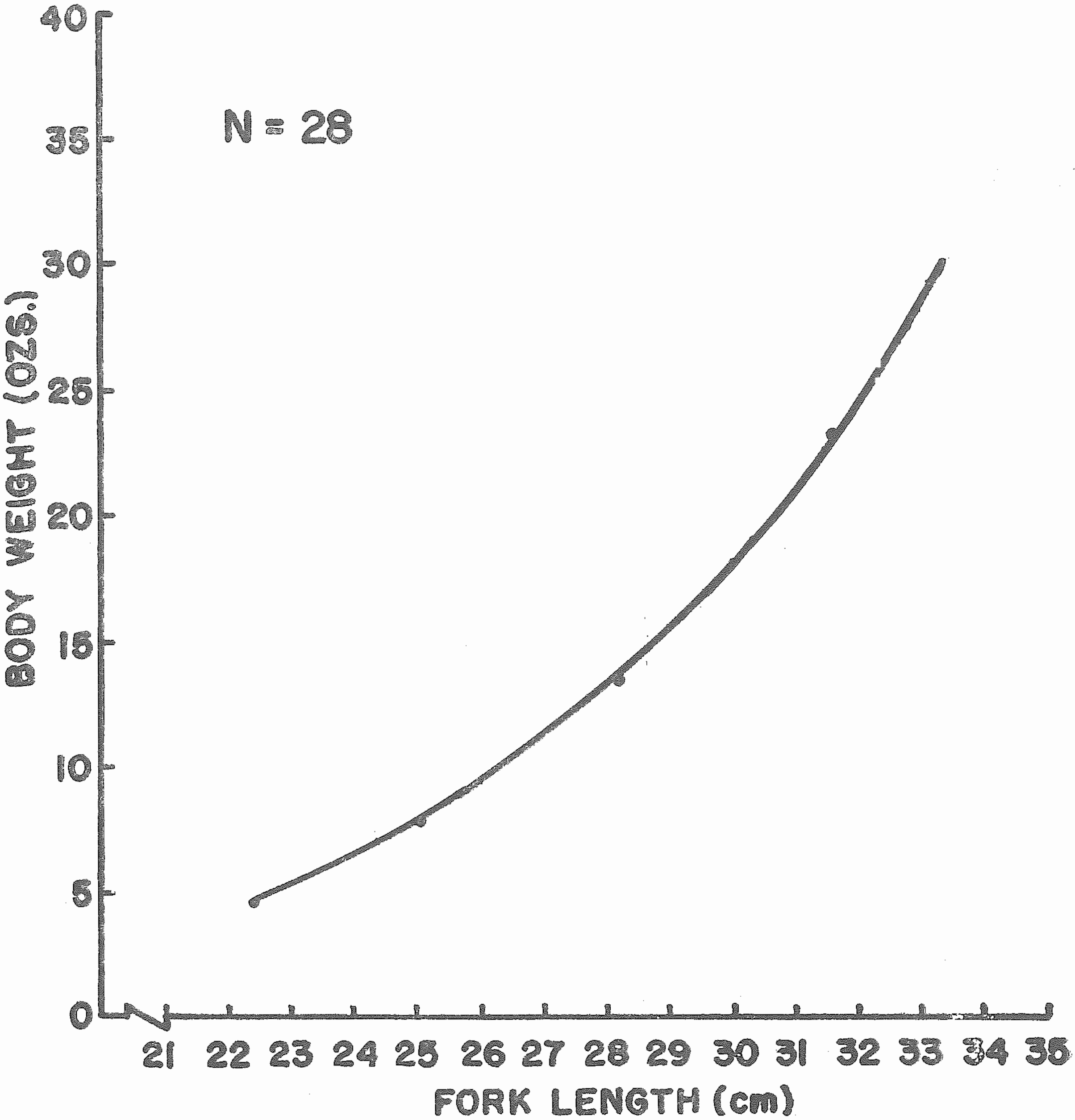

FIG. 13.

Fig. 13.—Length—weight relationship for A. rochei.

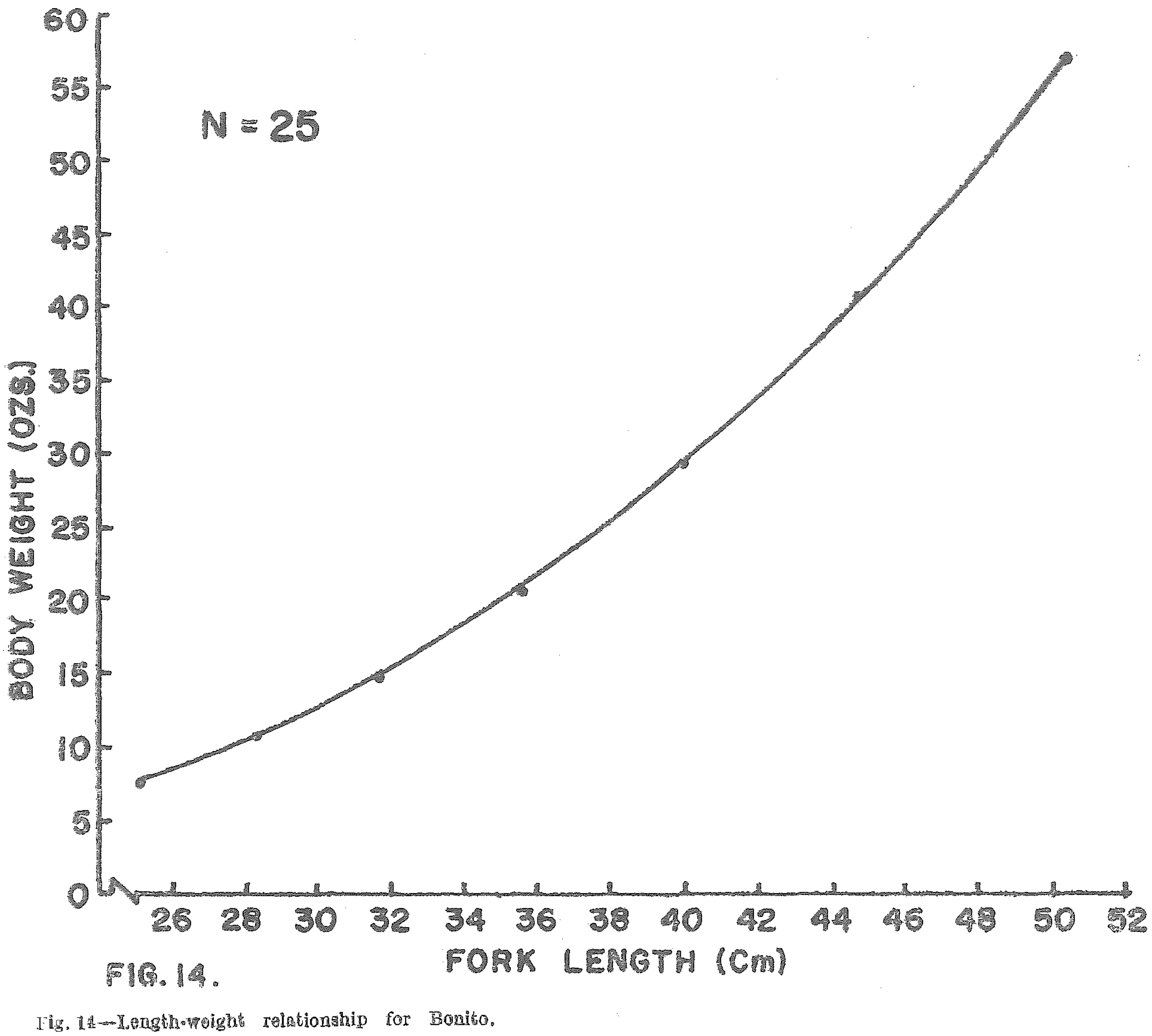

Fig. 14—Length-weight relationship for Bonito.

TABLE 1

Linear regressions of logarithmic length and weight for yellowfin tuna and the analysis of covariance to test the heterogeneity of regression coefficients

Area	*N*	$\bar{X}$	$\bar{Y}$	*Log a*	*b*	*Range of size*
S	9	1·8100	2·2355	—2·7395	2·8039	50—87 cm
SW	61	1·7113	1·9081	—1·1070	1·7619	34—60
W	12	1·8625	2·4033	0·8275	0·8461	68—95
E	10	1·9140	2·5180	—3·5010	3·1448	70—125
Common	92	1·8778	2·4020	—3·0403	2·8997	34—125

	Degree of Freedom	*Sum of Squares*	*Mean Square*	*F*
Deviation from regression within area	87	3·712	0·0426	
Deviation from individual regression	84	3·0518	0·0363	
Difference between regressions	3	0.661	0.220	6.0**

TABLE 2

Linear regressions of logarithmic length and weight for skipjack tuna and the analysis of covariance to tes heterogeneity of regression coefficients

Area	*N*	$\bar{X}$	$\bar{Y}$	*Log a*	*b*	*Size range*
S	23	1·6769	1·8670	– 4·4097	3·7434	38—52 cm
SW	43	1·6848	1·8704	– 4·8113	3·9659	48—66
W	7	1·7485	1·7400	– 0·1737	1·4271	59—60
E	15	1·7620	2·0920	– 2·9568	2·8654	52—67
Common	88	1·6846	1·8564	– 3·0250	2·8977	38—67

	Degree of freedom	*Sum of Squares*	*Mean Square*	*F*
Deviation from regression within area	83	0·8619		
Deviation from individual regression	80	0·5658	0·0070	
Difference between regressions	3	0·2961	0·0987	14·1**

TABLE 3

Linear regressions of logarithmic length and weight for mackerel tuna and the analysis of covariance to test heterogeneity of regerssion coefficients

Area	N	$\overline{X}$	$\overline{Y}$	Log a	b	Size range
S ..	45	1.4991	1.3022	−4.0846	3.5934	25–56 cm
SW ..	49	1.4887	1.1246	−3.770	3.3142	16–57
W ..	80	1.6118	1.5690	−3.4327	3.1032	12–57
E ..	27	1.7203	1.8781	−3.2068	2.7075	45–58
Common ..	201	1.5729	1.4424	−3.3154	3.0249	12–58

	Degree of Freedom	Sum of Squares	Mean Square	F
Deviation from regression within area ..	196	8.1871		
Deviation fron individual regression ..	193	3.9420	0.0204	
Difference between regressions	3	4.245	1.415	70.7**

TABLE 4

Linear regressions of the logarithmic length and weight for *A. thazard* and the analysis of covariance to test heterogeneity of regression coefficients

Area	N	$\overline{X}$	$\overline{Y}$	Log a	b	Size range
S ..	93	1.5349	1.3902	−3.3078	3.0610	30–41 cm
SW ..	22	1.4627	1.0272	−4.1215	3.520	24–54
W ..	31	1.6419	1.7309	−2.8976	2.8190	35–60
E ..	14	1.5414	1.3771	−2.4209	2.4640	30–40
Common ..	160	1.5463	1.4053	−3.7497	3.3338	24–60

	Degree of freedom	Sum of Squares	Mean Square	F
Deviation from regression within area ..	155	1.2552	0.00809	
Deviation from individual regression ..	152	0.840	0.00526	
Difference between regressions	3	0.4152	0.13840	26.6**